

Extending Battery Life With the TPS61040 White Light LED Driver

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ABSTRACT

This application note describes how to extend the battery life of a circuit that uses Texas Instrument's TPS61040 low power dc-dc boost converter for driving white light LEDs. Power loss in the current sense resistor is discussed, and a method for reducing this loss is presented. Design equations are given for calculating the proper resistor values for a white light LED driver that includes provisions for dimming the LED brightness.

A current source, rather than a voltage source, typically drives white light LEDs. The TPS61040 is ideally suited for this application. *TPS61040EVM-002 User's Guide*, TI literature number SLVU068 provides a detailed discussion of how to drive white light LEDs. To summarize, regulation of the LED current is accomplished by monitoring the voltage across a current sense resistor. Any power dissipated by the current sense resistor is lost and reduces battery life. The key to extending battery life is to reduce the losses in the current sense resistor.

Figure 1 shows a TPS61040 low power dc-dc boost converter application that drives four LEDs and includes the capability to dim the LED light output. The resistor values in Figure 1 were calculated using the equations in the *Analog Dimming with Analog Voltage* section of the EVM user's guide cited above. For this design, the maximum desired output current is 20 mA, and the current may be dimmed from 20 mA to 0 mA by injecting 0 V to 3.3 V into the VADJ pin. With these parameters, the full scale voltage across the current sense resistor, R4, with $I_{out} = 20$ mA is 2 V. This results in a power loss of 40 mW. The four LEDs in series only require a forward voltage of 12.7 V at 20 mA, but the circuit is forced to generate 14.7 V at 20 mA.

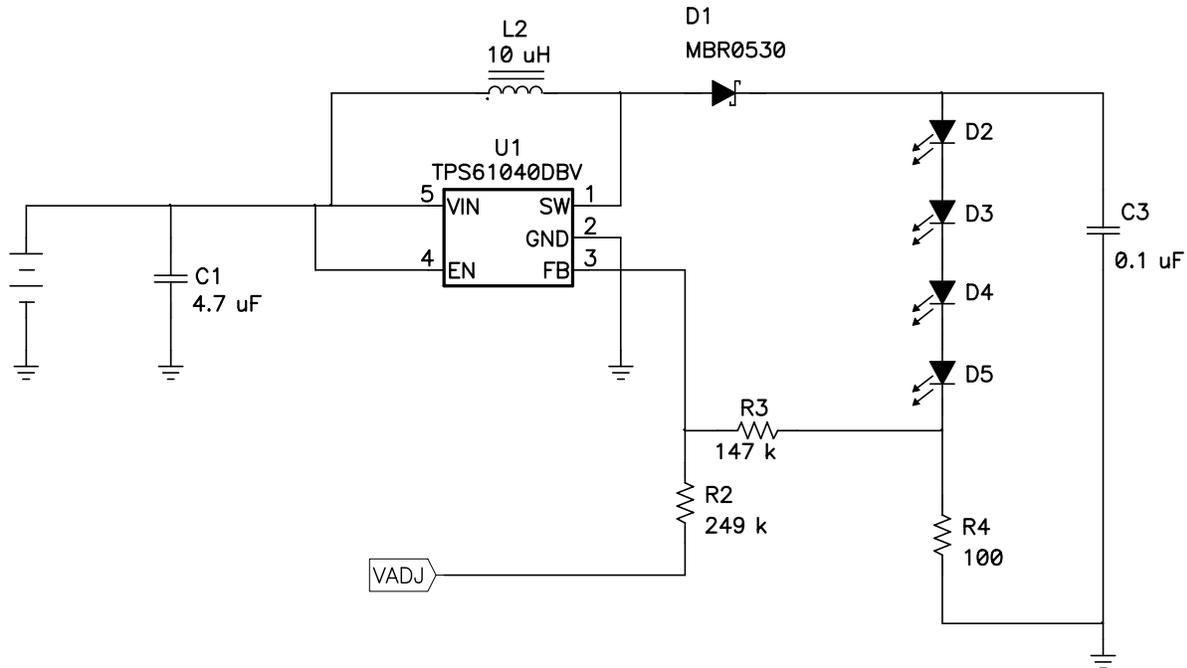


Figure 1. Standard TPS61040 White Light LED Driver

The voltage across the current sense resistor R4, along with the injected dimming voltage, must combine to equal the reference voltage in the TPS61040 (1.233 V). One way to reduce the full-scale voltage across the current sense resistor is to reduce the reference voltage in the TPS61040. As with most controllers, this is not an option because the reference voltage is internally generated and is not user adjustable. A second way to reduce losses in the circuit is to inject another voltage into the circuit to bias up the FB pin under no load conditions. With an additional resistor, the circuit may be designed such that the full-scale voltage across the current sense resistor is less than 2 V for a 20 mA output. The bias voltage can be a regulated voltage that is already available in the system. If another voltage is not available, the output voltage of the TPS61040 may be used. However, this increases the quiescent current during shutdown.

Figure 2 shows a TPS61040 application that drives four LEDs and includes the capability to dim their light output. The difference between the two circuits is the addition of Vbias and the Rbias resistor to Figure 2. The following equations calculate the correct resistor values for the circuit.

$$R_4 := \frac{V_{cs}}{I_{out_max}}$$

$$R_2 := R_{bias} \cdot \frac{(V_{adj_max} - V_{fb}) \cdot V_{cs} + V_{fb} \cdot (V_{adj_min} - V_{adj_max})}{(V_{fb} - V_b) \cdot V_{cs}}$$

$$R_3 := \frac{(V_{fb} - V_{cs}) \cdot R_{bias} \cdot R_2}{(R_2 \cdot V_b - R_2 \cdot V_{fb} + R_{bias} \cdot V_{adj_min} - R_{bias} \cdot V_{fb})}$$

Where:

Vcs is the desired maximum voltage across the current sense resistor.

Iout_max is the maximum LED current.

Rbias is the chosen value for the additional bias resistor.

Vadj_min is the minimum voltage used to adjust the LED current.

Vadj_max is the maximum voltage used to adjust the LED current.

Vfb is the reference voltage of the TPS61040 (1.233 V).

Vb is the bias voltage.

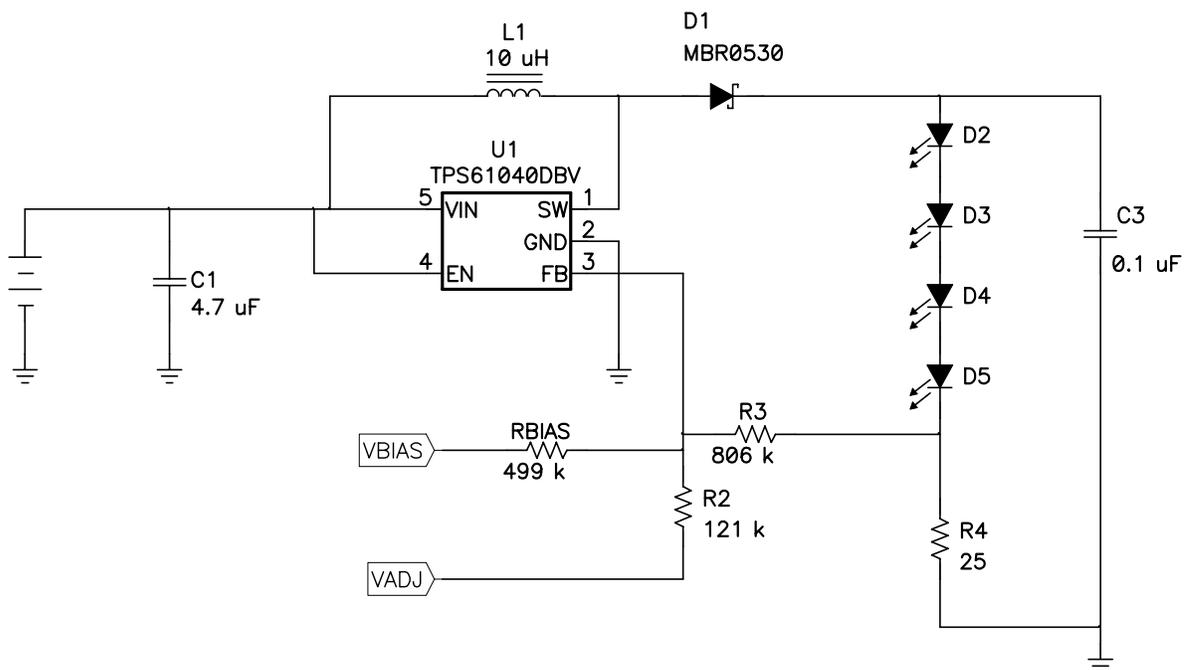


Figure 2. Improved White Light LED Driver Extends Battery Life

Table 1 provides resistor values for different bias voltages and different current sense voltages. Table 2 shows the operating parameters of the circuit under various conditions. The values shown in the $V_{cs}=2$ V column were measured using the circuit in Figure 1, and $V_{in}=3.6$ V. All other data are taken with the circuit in Figure 2. Note that although the efficiency of the circuit is essentially the same under all conditions, the battery current is reduced when the full-scale voltage drop across the current sense resistor is reduced. The battery life is calculated using a 1000-mA/hr Li-Ion battery.

Table 1. Calculated Resistor Values

V_{cs} (V)	0.5	0.5	0.5	0.25	0.25	0.25
V_{bias} (V)	3.3	5	12.7	3.3	5	12.7
R_{bias} (k Ω)	499	499	499	499	499	499
R_2 (k Ω)	1466	804	264	3430	1882	618
R_3 (k Ω)	222	122	40	260	143	47
R_4 (Ω)	25	25	25	12.5	12.5	12.5

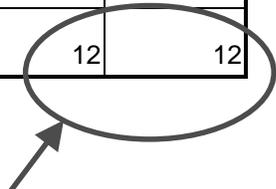
Table 2. Measured Data Shows Extended Battery Life

V_{cs} (V)	2	0.5	0.5	0.25	0.25
V_{bias} (V)	N/A	5	V_{out} (1)	5	V_{out} (2)
I_{out} (mA)	20	20	20	20	20
V_{out} (V)	14.77	13.17	13.17	12.92	12.92
I_{in} (mA)	95.8	84.9	85	83.1	83.4
Effic (%)	85.6	86.2	86.2	86.3	86.1
Battery Life at 100% duty (Hours)	10.4	11.8	11.8	12	12

(1) V_{out} is approximately 13.17V

(2) V_{out} is approximately 12.92V

15.4% Increase



References

1. *TPS61040 – Low Power DC/DC Boost Converter in SOT-23 Package (SLVS413)*
2. *TPS61040EVM-002 White Light LED Bias Supply Evaluation Module (SLVU068)*

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